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CORRESPONDENCE

Comments on "Objective Analysis of a Two-Dimensional Data Field by the Cubic Spline Technique"

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Fritsch (1971) concludes, "Objective analysis by the spline technique appears to be a satisfactory method for two-dimensional data analysis." It may be that the spline technique can be engineered to produce satisfactory analyses, but Fritsch has certainly not demonstrated this, and in fact, his applications suggest the contrary.

We agree with Fritsch that it is, ". . . imperative to begin any numerical weather prediction with the 'best possible' representation of the real data." However, the definition of "best possible" should consider the numerical model to be used. That is, "initialization" for the model and the objective analysis of all pertinent data available should be an integrated procedure. This is a very difficult problem and one that deserves much study. Certainly, the objective analysis methods used operationally now should be replaced when "better" techniques become available (computer time is, of course, a factor). However, the spline technique, as described by Fritsch, does not address the initialization problem and can, therefore, be satisfactory only to the extent that some measure of the difference between the data and the analysis is satisfactory. The examples shown by Fritsch do not appear to meet this criterion.

The evidence presented by Fritsch to support his conclusion consists of four spline analyses and their comparison with analyses produced by other methods. Each of these comparisons will be discussed below.

The first example is the analysis of data at the points shown in figure 5 interpolated from the field of values shown in figure 6 and known at 5° latitude-longitude intersections.[2] (Fritsch does not state the longitudinal grid length but it is evidently 5° since the array size is 18×72.) Actually, there are two interpolation problems here, that of interpolating from grid points to stations and that of interpolating from stations to grid points.

The spline analysis shown in figure 7 is considerably different in detail from the "true" analysis in figure 6. The error is about 200 m in the Cuba-Hispaniola area even though there are "stations" there. The closed 4400-m contour should be defined by the stations in the Aleutian region, but it is not reproduced by the spline analysis. On the East Coast of the United States from the southern tip of Florida to southern Delaware, a difference of 1400 m is analyzed as only about 1000 m.

Fritsch states that although other analyses (including Cressman's) ". . . give satisfactory results for regions of sufficiently dense observation stations, a reliable technique that will operate satisfactorily over regions of sparse data remains to be developed." The spline technique is offered in, "An attempt to develop such a technique. . . ." He later concludes, "Analysis of regions with poor data coverage also appears to give satisfactory results except in those situations where the features being analyzed are defined by less than three pieces of data." We feel figure 7 is not a satisfactory analysis in sparse *or* dense data regions.

Cressman's technique is used for comparison with the spline analysis. Only cursory comparison of figure 8 (which is labeled, "Cressman's approximation to the exact solution") with the exact solution in figure 6 reveals the analysis in figure 8 to be extremely poor. The gradients in many places have only about one-half the magnitude of the exact solution. Closer inspection of areas for which data were extracted (fig. 5) shows completely unrealistic values.

For example, a true value of 5000 m over the Louisiana Coast is analyzed as less than 4600 m. The low height center over the Kuril Islands bounded by a 3800-m contour is analyzed with a 4200-m contour even though several "stations" are in the vicinity, two of which are enclosed by the 3800-m contour. On the East Coast of the United States from the southern tip of Florida to southern Delaware, a difference of 1400 m is analyzed as about 600 m.

We know from many different applications that the Cressman successive approximation technique can be made to fit the data very closely even after smoothing to remove undesirable shortwave components. For instance, data available from the National Meteorological Center indicate that, for January 1962, the root-mean-square height differences between about 70 twice-daily observations in the United States and values interpolated from operational objective analyses were only 21.1 and 21.3 m for the 300- and 200-mb surfaces, respectively. We must, therefore, question the author's application of Cressman's technique reported in this paper.

In reference to the 850-mb temperature analyses (figs. 9 and 10), Fritsch states, "A comparison of objective and subjective analyses shows good agreement both along and across the front." Close inspection reveals that the 12.8°C difference between Dodge City, Kans. (DDC), and Oklahoma City, Okla. (OKC), is accounted for exactly by the subjective analysis, but the spline technique shows

[1] National Weather Service, NOAA.

[2] All figure numbers refer to Fritsch (1971).

only 8.8°C difference. Also, the spline analysis misses Amarillo, Tex. (AMA), by 6.1°C even though it appears to be a correct observation.

Figures 11 and 12 show 500-mb wind speed analyses. Although the analyst was able to fit his analysis to all reports except Peoria, Ill. (PIA), the axis of strongest winds is oriented differently on the spline analysis than on the subjective analysis. Amarillo (AMA) and El Paso, Tex. (ELP), were missed by about 9 and 15 kt, respectively.

The subjective analysis of 300-mb heights (fig. 14) accurately accounts for the large gradient defining a jet while the spline analysis (fig. 13) does not. In particular, the 257-m difference between Albuquerque, N. Mex. (ABQ), and El Paso (ELP) is shown as about 110 m on the spline analysis. The low height center is displaced by about 200 mi and for many stations the analysis does not fit the data in an acceptable manner.

Therefore, on the basis of the evidence presented, we must conclude that the spline technique as used by Fritsch is *not* a satisfactory method of two-dimensional data analysis.

REFERENCES

Cressman, George P., "An Operational Objective Analysis System," *Monthly Weather Review*, Vol. 87, No. 10, Oct. **1959**, pp. 367–374.

Fritsch, J. Michael, "Objective Analysis of a Two-Dimensional Data Field by the Cubic Spline Technique," *Monthly Weather Review*, Vol. 99, No. 5, May **1971**, pp. 379–386.

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Reply

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In using an objective analysis that was *based on* the Cressman (1959) technique, it was not my intention to directly compare the actual Cressman technique (in its entirety) to the spline technique. Indeed, it was pointed out that the actual Cressman method could not be used since a preliminary forecast field was not available. It was desirable, however, to establish some type of comparison between the spline technique and the common "weighting" techniques. Apparently, the selection of mean latitudinal heights for a preliminary field (in combination with the particular size and number of data scans) placed too severe a restriction on the weighting method. In this regard, the comparison should not cast any reflection on results obtained by the explicit application of the actual Cressman method of analysis. Certainly, the everyday applications of Cressman's method serve to validate the successful operation of his technique.

With regard to the spline technique, certain persistent errors in the location and intensity of major analysis features have been identified, and the original method has been subsequently modified to adjust for these errors.

REFERENCE

Cressman, George P., "An Operational Objective Analysis System," *Monthly Weather Review*, Vol. 87, No. 10, Oct. **1959**, pp. 367–374.

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